

Assessment of the Major Causes of Dust-Resultant Haze in the WRAP

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1. Introduction

Suspended dust is one of the principal causes of haze at Class I areas in the Western United States. The magnitude of the impact of dust on haze varies by region as well as by season. Dust is the principal component of haze on the 20% worst haze days of the year (“worst days” hereafter) most frequently in the southwestern United States. However, every state in the Western Regional Air Partnership (WRAP) contains an IMPROVE monitor that registers dust as the principal component of haze on a worst day. On a seasonal basis, dust has the greatest impact on the largest number of monitoring sites in the spring, followed by summer and fall.

Sources of fugitive dust can vary greatly in spatial scale, time, location, and causes of emission. For example, paved and unpaved road dust emissions tend to follow the diurnal trends associated with motor vehicle traffic, with some additional dependence on seasonal occurrences such as snow and agricultural activities. Windblown dust emissions generally occur over larger spatial scales and the magnitude of dust emissions during these events can eclipse the comparatively smaller, but more regular road dust emissions. On a transcontinental scale, enormous, regional dust storms can be transported across continents and impact the entire WRAP region.

The work described herein aims to specifically identify the primary causes of dust measured in the WRAP region. The methodology focuses on periods when dust was the principal contributor to haze during worst days (worst dust days, hereafter). That is, we only consider days that are among the 20% worst for the given calendar year – with regard to reconstructed extinction – when dust was the largest component of B_{ext} . Within the resources of this potential project, it is unlikely that every worst dust day could be attributed to a specific source. Instead, we aim to assign individual worst dust days at an IMPROVE site within WRAP to one of a set of source classes. Much of the effort expended would focus on development of a new methodology for such an assessment. Therefore, there exists no *a priori* knowledge of the number of source classes that can be uniquely identified with confidence.

The work proposed here would leverage the expertise and tools currently being used as part of the WRAP Causes of Haze Assessment (COHA) project.

1.1. Objectives

1. Develop and document a methodology for assigning worst dust days at IMPROVE monitors within the WRAP domain to a set of source classes.
2. Use methodology to categorize worst dust days in the WRAP domain over the period 2001 – 2003. **If the 2003 data are not available in time to meet the delivery schedule below, then only 2001 – 2002 will be included and a contract extension (for both the project period and additional financial resources) will be necessary to meet these objectives.**

2. Background

The concentration of dust is operationally defined as the sum of the concentrations of Fine Soil Mass (FS) and Coarse Mass (CM) as measured by monitors in the IMPROVE network, which operates 24-hr filter samples on a one in three day basis (Since 2001). CM is the difference between PM₁₀ and PM_{2.5}. FS is calculated from a linear equation based on the measured concentrations of five metals believed to be associated with mineral dust: Al, Si, Ca, Fe, and Ti.

The visibility extinction resulting from suspended aerosols (i.e. does not include Rayleigh scattering) is quantified through the extinction coefficient, B_{aer} , which is calculated from the equation:

$$B_{aer} = 3F(RH)[SO_4] + 3F(RH)[NO_3] + 4[OMC] + 10[LAC] + 1[FS] + 0.6[CM]$$

Equation 1

$$B_{dust} = [FS] + 0.6[CM]$$

Equation 2

where the brackets indicate concentrations in $\mu\text{g}/\text{m}^3$ and SO_4 , NO_3 , OMC, and LAC refer to estimates of sulfate, nitrate, organic carbon, and light absorbing carbon, respectively. The visibility extinction due to dust, B_{dust} is accordingly defined as the sum of the last two terms in Equation 1.

Both B_{aer} and B_{dust} are only estimates of the actual extinction caused by all aerosols and dust, respectively. In addition, the terms that appear on the RHS of Equation 1 and Equation 2 are themselves estimates of the species concentrations. Thus, estimates of the contribution of dust to aerosol extinction are inherently subject to both positive and negative biases. For example, Coarse Mass originating from sea spray, non-soil organic debris, or from wildfires would result in an overestimate of B_{dust} compared to the actual light extinction caused by ambient airborne dust.

3. Scope of Work

The objective is, to the extent possible with available resources, to assign a source class to each of the worst dust days in the WRAP domain when B_{dust} is the principal (largest) contributor to aerosol extinction. The period considered in this analysis will be limited to the most recent three-year period (2001 – 2003) in order to make use of the large number of IMPROVE monitors in WRAP that have commenced operation since the year 2000.

The analysis will begin by placing all worst dust days in a pooled set, examining common and differentiating characteristics among those days, and then successively removing days that can be explained (with confidence) by a particular source category. For example, regional windblown dust episodes are comparatively easy to identify. The simultaneous occurrence of high winds, large spatial extent of dust impact (i.e. large enough to include two or more monitoring sites), comparatively high CM to FS ratios may be a strong indicator for regional windblown dust. If confirmed, then all worst dust days that meet these criteria would be assigned to the “Regional Windblown Dust” source class and removed from the pool of worst dust days.

This analysis will start with the source classes that are easiest to identify (such as regional windblown dust) and proceed to the more difficult source classes. The set of tools used to achieve these results will evolve as the analysis proceeds, but is likely to include: spatial analysis of dust impact patterns, synoptic scale weather maps, data from meteorological stations representing individual sites, back-trajectory analyses, ratio of chemical constituents, ratios of aerosol size fractions, examination of documented wildfire databases, satellite imagery, emissions models (e.g. Naval Research Laboratory), and examination of land use in site vicinity. Additional Air Quality monitoring data from EPA’s AIRS network may also be used to supplement the analysis and to fill in spatial gaps in the IMPROVE network. Specifically, AIRS data would be used in cases when urban air quality monitors are close enough to the IMPROVE monitor of interest to be considered useful and when such data would be of utility in assessing the causes of a worst dust day at that IMPROVE monitor.

Within the resources available, it will not be possible to confidently assign every worst dust day in 2001 – 2003 to a specific source category. There may be a number of sources that are difficult to differentiate with confidence. For example, road dust and construction dust may be correlated and similar in chemical composition. Windblown dust caused by a localized thunderstorm may be difficult to confirm due to poor spatial resolution of synoptic weather maps and the absence of surface meteorological data in the vicinity of the monitoring site. All worst dust days that cannot be assigned to a source category with confidence will be labeled as “Unknown Source”. A preliminary list of possible “Causes of Dust” and their characteristics is provided below:

1. **Transcontinental Events:** Very large scale events that are capable of transport across continents. Examples include Asian and Saharan dust.
2. **Regional Windblown Events:** Windblown dust that affects multiple sites within a region that is impacted by regional scale weather characterized by high winds. These events are known to occur often in the southwestern US, especially in the spring.

3. **Wildfire-Related Events:** Wildfires can result in either a false identification of dust through organic contribution to CM or actual emission of dust due to resultant high winds. If wildfires result in worst dust days, ratios of OMC, FS, CM, and other chemical identifiers will be examined.
4. **Local Windblown Dust:** Small scale weather patterns such as isolated thunderstorms can result in locally elevated dust concentrations. These weather events can be difficult to identify, since they may not appear on regional scale weather maps. Nearby meteorological data – If available- can be used to examine the possibility of local windblown dust.
5. **Other Events:** As part of this analysis, patterns and characteristics that are unique to other types of dust events may be uncovered. Whenever sufficient data are available to create a new category, DRI will do so.
6. **Unknown Source:** This category would include events that are caused by one of the previously enumerated categories but that do not meet the criteria for those categories (i.e. false negatives). This category also includes events that are more difficult to identify such as the influence of road dust from a nearby urban area or very nearby unpaved road. One of the goals of the method to be developed is to minimize the number of worst dust days that appear in this category without compromising the confidence that can be placed in the previously enumerated categories.

4. Deliverables

Similar to the existing Causes of Haze Assessment, the results of this project would not be provided in a report as such. Instead, documentation and data would be made available through the COHA web site.

4.1. Documentation of Methodology – Framework for an evolving approach

The methods developed will be documented and explained so that they may be repeated and built upon in the future. To demonstrate how the method works in practice, for each source category an illustrative example case will be provided. For instance, if one of the source categories is “dust suspended by wildfires”, then we will provide a step by step example of a worst dust day that has characteristics which make it appropriate for this source category.

4.2. Application of Methodology to 2001 – 2003 20% Worst Days with Dust as Principal Component

The method developed for categorizing the sources of worst dust days will be applied to the monitoring data from the years 2001 – 2003. On a per site basis, the types of source categories, their frequency of occurrence, and the spatial scale of their influence will be summarized on an annual and seasonal basis. In addition to summarizing the results on a site by site basis, wherever possible, the location and scale of influence of the source(s) of dust will be identified at the appropriate scale. For example, for a regional windblown dust event, we will identify the boundaries of the region that is influenced by the event as well as attempt to identify the states – or areas of states – where the windblown dust may

have originated. If agricultural dust is identified as the primary contributor to a worst dust day at a particular site, we will attempt to identify the agricultural area where the dust may have originated from and the IMPROVE monitors that were impacted sufficiently from the agricultural dust to be characterized as a worst dust day.

There are accordingly two deliverables from this portion of the project. The first is a summary of the results of the analysis on a site by site basis that enumerates the frequency of occurrence of worst dust days due to a particular source category. The second is an assessment of the scales of influence of specific dust categories. The embodiment of this, latter deliverable will be developed by DRI in consultation with the DEJF and may consist of illustrative figures, data tables, and/or a categorization scheme, where for example, a regional windblown dust event would be categorized by its cause, scale, and region of influence.

5. Cost and Schedule

Work on this project will commence on May 1, 2004 and be completed by December 31, 2004. The cost for this project is estimated at \$50,000 (See attached budget) and is associated largely with DRI Professional salaries. A small portion of the budget is assigned to travel expenses (conferences and DEJF meetings) and miscellaneous supplies.

5.1. Milestones and Reporting

Assuming a project start date of May 1, 2004, the following table provides a schedule of milestones and progress reports.

Milestone/Deliverable	Date
1. A preliminary methodological approach is identified and tested with a small number of test episodes. This methodology will be presented to the DJEF during the July, 2004 meeting. Comments and suggestions provided by the DJEF will be used to refine the methodology.	July, 2004
2. Refined methodology will be applied to 1 year of data (probably 2002) for all WRAP sites. Results will be presented to DJEF in late September, 2004. A second round of comments and suggestions on the methodology used will be solicited from the DJEF at this time.	September 30, 2004
3. Methodology will be finalized and applied to all WRAP sites over the 2001-2003 period. Documentation of methodology and test episodes will be finalized and summaries of spatial and seasonal trends will be completed and available for posting on the COHA web site.	December 31, 2004

DESERT RESEARCH INSTITUTE COST ESTIMATE

Sponsor: WRAP DEJF

Project: Causes of Dust

Project Period: 05/01/04 - 12/31/04

Task 1	Task 2	Total
Develop Methodology	Apply to 2001 and 2003 Worst Dust Days	

DETAILED BUDGET	Rate	Units	Amount	Units	Amount	Units	Amount
Salaries:							
V. Etyemezian	\$5,778	0.50	\$2,889	0.40	\$2,311	0.90	\$5,200
J. Xu	\$5,178	0.50	\$2,589	0.70	\$3,624	1.20	\$6,213
D. Dubois	\$5,355	0.10	\$536	0.50	\$2,678	0.60	\$3,214
M. Green	\$9,023	0.20	\$1,805	0.00	\$0	0.20	\$1,805
Hourly Assistant	\$2,400	0.00	\$0	1.40	\$3,360	1.40	\$3,360
Subtotal Salaries		1.30	\$7,819	3.00	\$11,973	4.30	\$19,792
Fringe Benefits:							
Professional	39.1%		\$3,057		\$3,368		\$6,425
Hourly Assistant	9.7%		\$0		\$326		\$326
Subtotal Fringe Benefits			\$3,057		\$3,694		\$6,751
Total Labor			\$10,876		\$15,667		\$26,543
Travel:							
Airfare	300	1.00	\$300	2.00	\$600	3.00	\$900
Per Diem	120	2.00	\$240	4.00	\$480	6.00	\$720
Ground Transportation	40	2.00	\$80	2.00	\$80	4.00	\$160
Subtotal Travel			\$620		\$1,160		\$1,780
Other Costs:							
Laboratory							\$0
Supplies			\$50		\$50		\$100
Copying/Communications			\$218		\$313		\$531
Computer Usage Fee	1.54	1.30	\$360	1.60	\$444	2.90	\$804
TOTAL OTHER COSTS			\$628		\$807		\$1,435
TOTAL DIRECT COSTS			\$12,124		\$17,633		\$29,758
INDIRECT COSTS	69%		\$8,366		\$12,167		\$20,533
TOTAL COST			\$20,490		\$29,801		\$50,290
DRI Cost Share							\$290
Final Cost			\$20,490		\$29,801		\$50,000